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Abstract

DEVELOPMENT OF FUEL AND COOLANT TUBES FOR A REACTOR COOLED BY ORGANIC LIQUID

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1. The first experimental reactor (WR-1) at Canada's Whiteshell Nuclear Research Establishment will be moderated by D_2O, cooled by organic liquid, and have vertical pressure tubes. The first pressure tubeswill be stainless steel and the first fuel will be UO_2. It is planned also to develop uranium carbide fuel and eventually to replace the pressure tubes using materials of low neutron absorption suitable for power reactors. This paper describes the development work on UO_2 fuels and on possible power-reactor pressure tubes.

2. The properties of SAP (sintered aluminum product) have been studied at high temperatures. Ultimate tensile strengths and total elongations have been measured on standard tensile specimens; axial creep, internal pressure creep and hoop stress rupture have been measured on tubes. The mechanical properties depend to a degree on the method of powder production and it may be possible to find improved methods of fabrication.

3. The fuel design is a 19-element rodded cluster with a rod separation of 1 mm, maximum sheath temperature of 500 °C, and fuel channel outlet temperature of 370 C. Sheathing materials are SAP and Zr-2.5%Nb. End closures in SAP have been achieved by pressure bonding and resistance welding and in Zr-2.5%Nb by shielded-arc and resistance welding.

4. Heat transfer to organic liquid has been studied under simulated reactor conditions and heat fluxes that cause departure from nucleate boiling (DNB) have been established. Local heat-transfer coefficients have been measured in open regions, in gaps between elements and in the vicinity of helical spacers in simulated fuel bundles. Those in the open regions agree with those measured in simple annular channels and are proportional to Re^n where $n > 0.8$. The DNB heat fluxes decrease with increasing test-section length up to 35 cm; beyond 35 cm they remain constant. For similar lengths they agree with data published by Atomics International.

5. Nine irradiation tests have been made on SAP-sheathed UO_2 fuels in the X-7 loop of the NRX reactor at $\int \lambda \, d\theta$ values of ~ 36 W/cm and sheath temperatures of 450 - 500°C. Four of these experiments resulted in sheath failures; two of these are considered to be significant. The significant failures occurred in SAP-930 (7% Al_2O_3). The mechanism of failure has not been established but there is some evidence that a stronger material such as SAP-895 (10%Al_2O_3) will be more resistant to failure. The results of an irradiation test made on UO_2 sheathed in Zr-2.5%Nb at a sheath temperature of 475°C are sufficiently encouraging to make Zr-2.5%Nb a contender for sheathing material.

6. Two coolant tube concepts are under development: externally insulated hot pressure tubes and internally insulated cold stress tubes. Hot pressure tubes of Zircaloy-4 have been tested in the X-7 loop; SAP hot pressure tubes are being tested in laboratory organic-coolant rigs. Zirconium-alloy cold stress tube assemblies, internally insulated with compressed silica fibre and lined with either SAP or zirconium-alloy tubes have performed well in laboratory tests. Irradiation tests are being made on the solid insulants to evaluate their stability. Techniques for mechanically joining SAP and zirconium-alloy tubes to ferrous metals have been developed and joints are under test.